



## Characteristics and contaminants of the Salton Sea sediments

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### Abstract

This was the first comprehensive study to evaluate the distribution of sediment types and sediment contaminants throughout the Salton Sea. The sampling effort encompassed the entire Sea plus its three main tributaries, and included collection of sediment samples from 73 locations. The agricultural runoff that keeps the Sea alive is loaded with salts, pesticides, selenium, and other metals. Metals and metalloids found at elevated concentrations and of potential ecological concern were cadmium, copper, molybdenum, nickel, zinc, and selenium. The most significant metalloid of concern was selenium, which was limited to the upper 30 cm of sediment. There did not appear to be any strong correlation between the sand, silt, or clay content with the areas of elevated metals and metalloids. Acetone, 2-butanone, and carbon disulfide were also widespread but appeared to be associated with natural biological processes within the sediments. One of the most significant findings of this study was the absence of elevated concentrations of organic chemicals commonly used in agriculture earlier this century, such as dichlorodiphenyltrichloroethane (DDT).

### Introduction

The Salton Sea is the largest lake in California, with a current length of 56 kilometers (km), width of 24 km, and maximum depth of approximately 15 m. It is approximately 85 m below mean sea level and its salinity is 44 parts per thousand. The Sea is a closed drainage system that receives 5.8 cm of rain a year, with air temperatures reaching 50 °C. Agricultural wastewater keeps the Sea alive and carries contaminants such as pesticides, selenium, and other elements, as well as salt leached from the agricultural fields.

Previous studies on Salton Sea bottom sediments have identified a variety of elements and organic chemicals including organochlorine pesticide residues of banned DDT (1,1,1-trichloro-2,2-bis[p-chlorophenyl]-ethane) and its derivatives, DDD (1,1-dichloro-2,2-bis[p-chlorophenyl]-ethane) and DDE (1,1-dichloro-2,2-bis[p-chlorophenyl]-ethylene). Many chemicals, including DDT, DDD, DDE, dichloromethane, polychlorinated biphenyls, polynuclear aromatic hydrocarbons, pesticides, selenium, and boron, have been identified in the riverbeds feeding into the Sea (Hogg, 1973; Eccles, 1979; Setmire & Stroud, 1990; Setmire et al., 1993; Bechtel, 1997). Prior to the current study, however, little was known about the

current concentrations and distribution of these contaminants within the sediments of the Salton Sea. This is the first comprehensive study to evaluate the overall distribution of sediment types and contaminants throughout the Sea and its three major tributaries. A major objective of the study was to provide information that would be useful for development of effective management actions to save this valuable ecosystem.

### Description of site studies

This investigation of the physical and chemical characterization of sediments in and around the Salton Sea, Imperial and Riverside Counties, California, was undertaken in the winter of 1998–1999. The study was implemented in two phases. In the first phase, sediments were sampled from December 15 through 22, 1998. The samples were analyzed for contaminant concentrations and particle size distribution in the bottom sediment of the Sea plus approximately 1.6 km up each of three of its main tributaries: the Whitewater, the Alamo, and the New rivers. Phase I sediment samples were collected from 42 grab sampling sites and six core sampling sites.

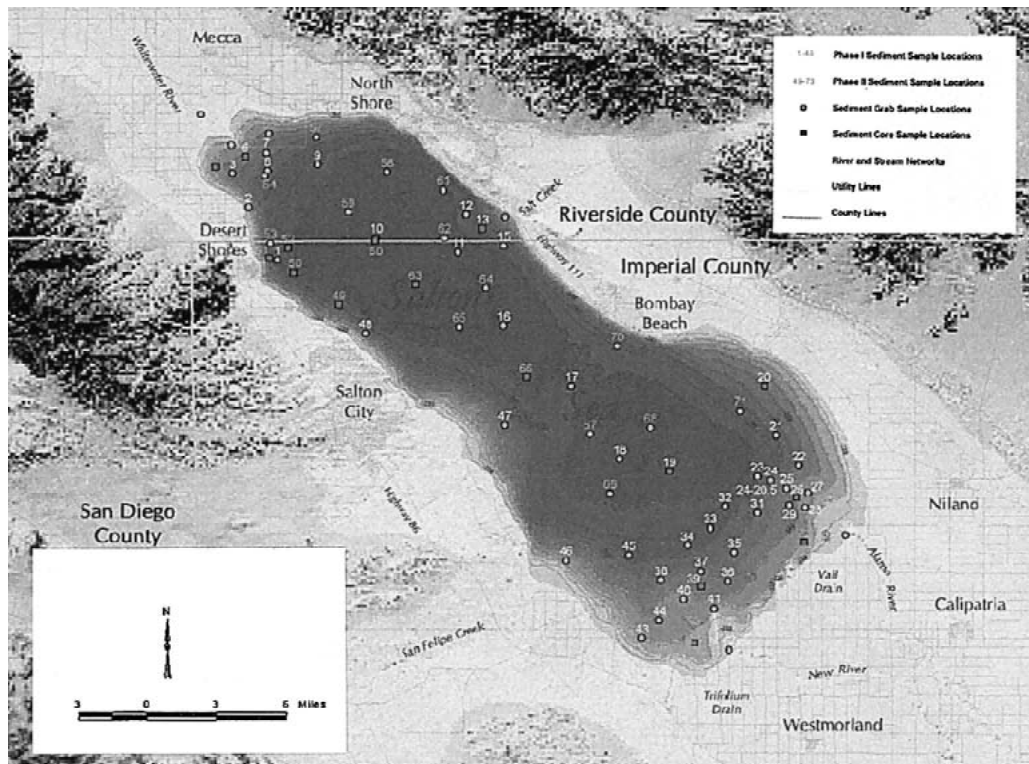


Figure 1. Phase I and II sampling locations.

Based on the results of the first phase of investigation, a second phase of sediment sampling was conducted from January 19 through 22, 1999, to further assess and measure contaminant concentrations and evaluate particle-size distribution in the bottom sediment. This second sampling phase focused on the significant areas of interest identified during Phase I and included sediment sampling at 15 grab sites and 10 core sites. The locations of Phase I and Phase II sampling sites are shown on Figure 1 above.

### Materials and methods

A stainless-steel modified Birge-Ekman-style box sediment sampler, 15.24 centimeters (cm) by 15.24 cm by 15.24 cm in size, was used to collect samples at the 57 grab sample locations of the 73 sampling sites. For each grab sample, up to 710 cubic centimeters of material was retained for inorganic and organic chemical analyses, depending on sample recovery. Sediment samples were transferred directly from the sampling equipment into clean, laboratory-grade glass jars using a stainless-steel trowel.

The core samples were collected using an AMS stainless-steel soft sediment sampler that can produce a 5-cm square by 182-cm long core. The corer can take up to 182 cm of undisturbed samples from soft sediment, provided that rocks or dense materials are not encountered. The AMS soft sediment sampler consists of two stainless steel, 182-cm long, right-angle-shaped sampler halves, each with a pointed lower end, that create a 5.08-cm square when locked together. One half contains a riveted sediment trap that engages when the sampler is pulled from the sediment. Sediment samples obtained using the stainless steel corer were collected from a boring advanced down to a maximum of 182 cm below ground surface (bgs), with samples for laboratory analyses taken at 30-cm intervals. The cores were carefully measured for total length and different layers of sediment without disturbing the sediment-water interface. Cored samples were lithologically described and classified using the Unified Soil Classification System. As with the grab samples, these samples were transferred to clean, laboratory-grade glass jars using a stainless steel trowel that was cleaned between samples.

Each sediment sample was analyzed for particle size, total metals and metalloids consisting of the California Code of Regulations 17 metals series (antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc) using EPA Method 7000S, volatile organic compounds using EPA Method 8260, semi-volatile organic compounds using EPA Method 8270, chlorinated pesticides and polychlorinated biphenyls (PCBs) using EPA Method 8081, organophosphate and nitrogen pesticides using EPA Method 8141, and chlorinated herbicides using EPA Method 8151. A number of sediment samples were also analyzed for chlorinated pesticides using EPA Method 8270 as a confirmatory measure (EPA, 1980).

## Results and discussion

Sediments sampled on the bottom of the Salton Sea consisted of silt, clay, and finer grained sands. The shallow sediment also included abundant barnacle shells and occasional fish bones. The surface sediment composition included a high percentage of sand outside Salton City and extending into the central, deeper parts of the Sea. Sand percentages near the mouths of the New and Alamo rivers were also high, as expected, from deposition of these heavier particles from higher velocity inflows into the Sea. The lower velocity Whitewater River delta, on the other hand, was predominantly silt. Silt was also abundant along the southwest near-shore area and along the shallow water bays near the New and Alamo rivers. A shallow layer of clay blankets the southwestern corner of the Sea and extends toward the center, near the deepest part of the Sea. Clay is also abundant near shore and offshore just north of Desert Shores. The majority of the deeper sediment sampled consisted predominantly of varied amounts of silt and clay, with lesser amounts of fine sand. The distribution of sand, silt, and clay determined from this study are depicted in Figures 2, 3 and 4, respectively.

Concentrations of metals and metalloids in the sediments were found to be higher in the northern part of the Sea. Concentrations were generally higher in the upper 30 cm of sediment. The chemical concentrations were compared against background and available sediment quality screening criteria commonly used in sediment assessment studies of saline environments: maximum 'baseline value' for soils of the western United

States (Severson et al., 1987; modified from Shacklette & Boerngen, 1984) and National Oceanic and Atmospheric Administration (NOAA, 1991) effects range low (ERL) and effects range medium (ERM). For selenium, California Regional Water Quality Control Board, San Francisco Region, criteria for wetlands creation (Wolfenden & Carlin, 1992) were used because no ERLs or ERMs exist. NOAA ERL and ERM levels were used as a preliminary screening tool to define apparent elevated concentrations within the Sea. Based on these screening criteria, the following metals and metalloids were determined to be elevated and of potential ecological concern: cadmium, copper, molybdenum, nickel, zinc, and selenium, with the most elevated inorganic constituent being selenium.

Concentrations of cadmium ranged from 0.67 to 5.8 milligrams per kilogram (mg/kg). The highest reported concentrations of cadmium were found in the north-central part of the Sea. Concentrations of copper ranged from 8.1 to 53 mg/kg. The highest concentrations of copper were found near the mouth of the Whitewater River. Concentrations of molybdenum detected in the north and central part of the Sea ranged from approximately 11 to 194 mg/kg. The range of reported concentrations for nickel was from 3.3 to 33 mg/kg. The highest concentrations of nickel were detected at the mouth of the Whitewater River and in the deeper portion of the Sea. The range of concentrations for zinc was from 5.4 to 190 mg/kg. The highest concentrations of zinc were found at the mouths of the Whitewater River and Salt Creek. Concentrations of selenium detected at the Sea ranged from 0.086 to 8.5 mg/kg. The highest concentrations of selenium were found just offshore of Desert Shores. In general, metal and metalloid concentrations were elevated over much of the northern half of the Sea. The distribution of detected concentrations of cadmium, molybdenum, nickel, and selenium are depicted in Figures 5, 6, 7 and 8, respectively.

Elevated concentrations of organic chemicals in sediment were detected predominately in the northern part of the Sea. Of the 118 sediment samples analyzed for volatile organic compounds, 114 samples contained detectable concentration of acetone, carbon disulfide, and/or 2-butanone. These three detected chemicals are believed to be present as a result of natural biological anaerobic degradation processes occurring within Salton Sea sediment. Acetone concentrations ranged from 32 to 840 micrograms per kilogram ( $\mu\text{g/kg}$ ). The highest concentrations of acetone were located near the mouth of the New River.

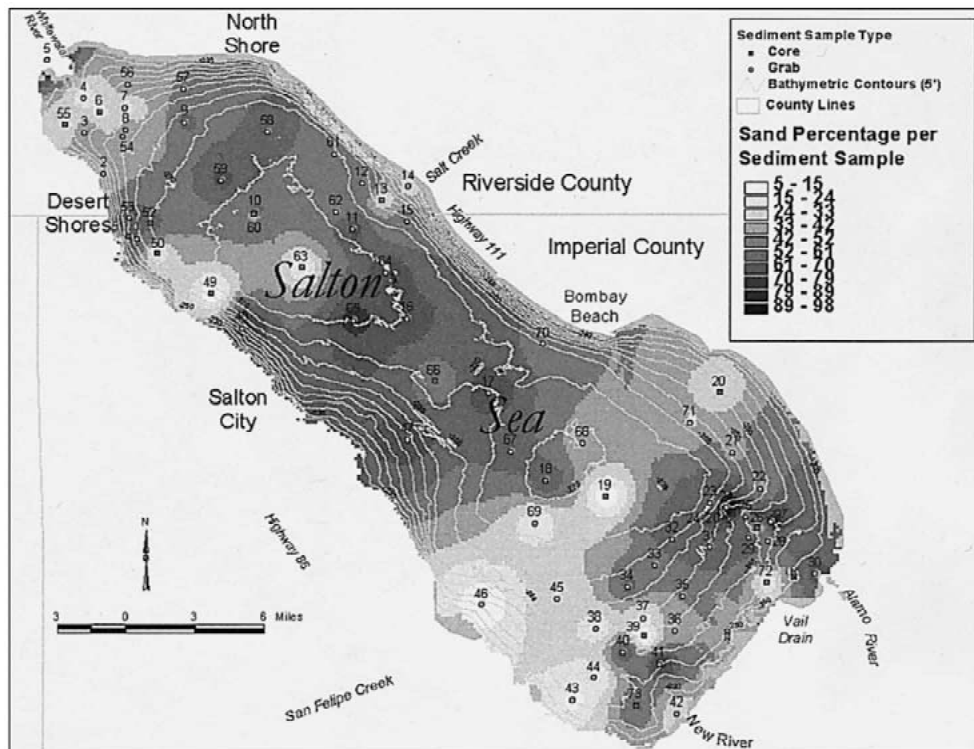


Figure 2. Sand percentage per sediment sample.

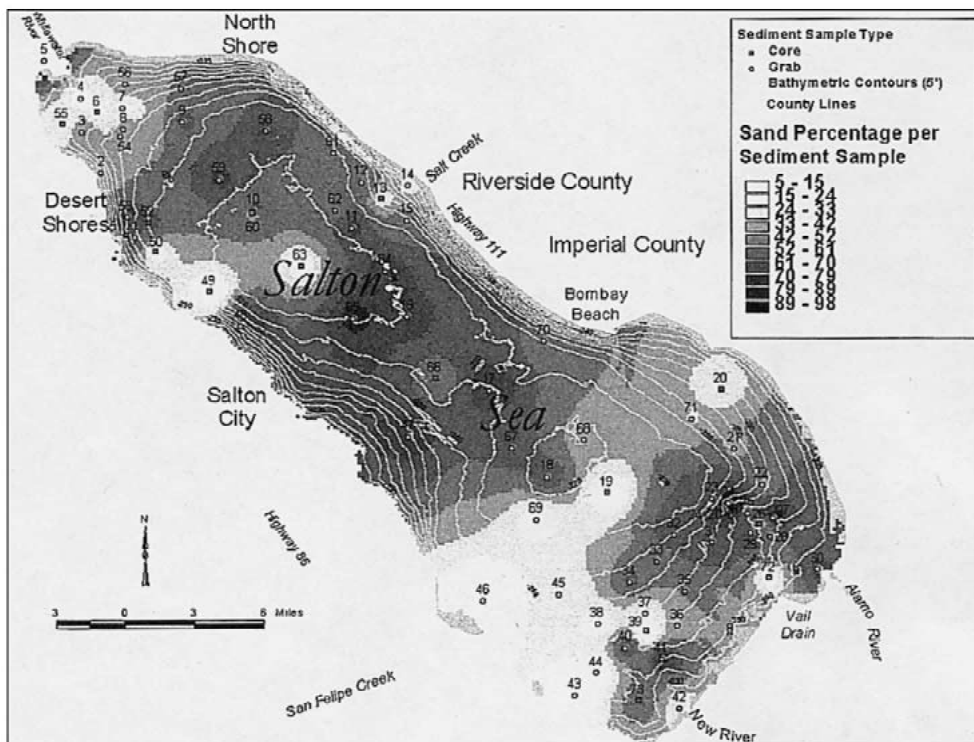


Figure 3. Silt percentage per sediment sample.

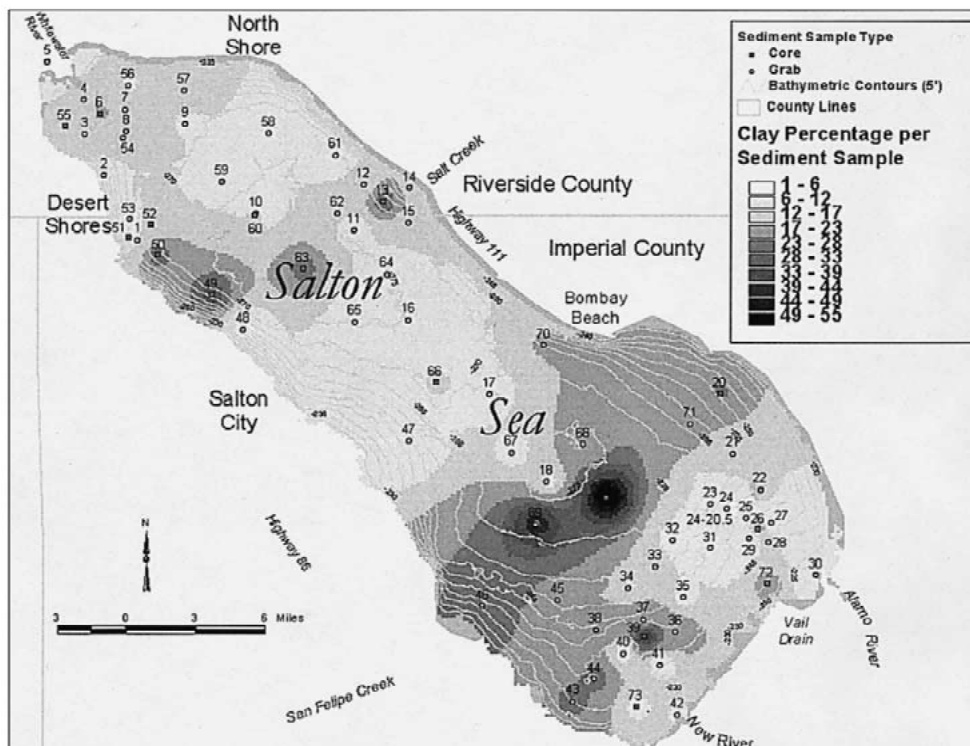


Figure 4. Clay percentage per sediment sample.

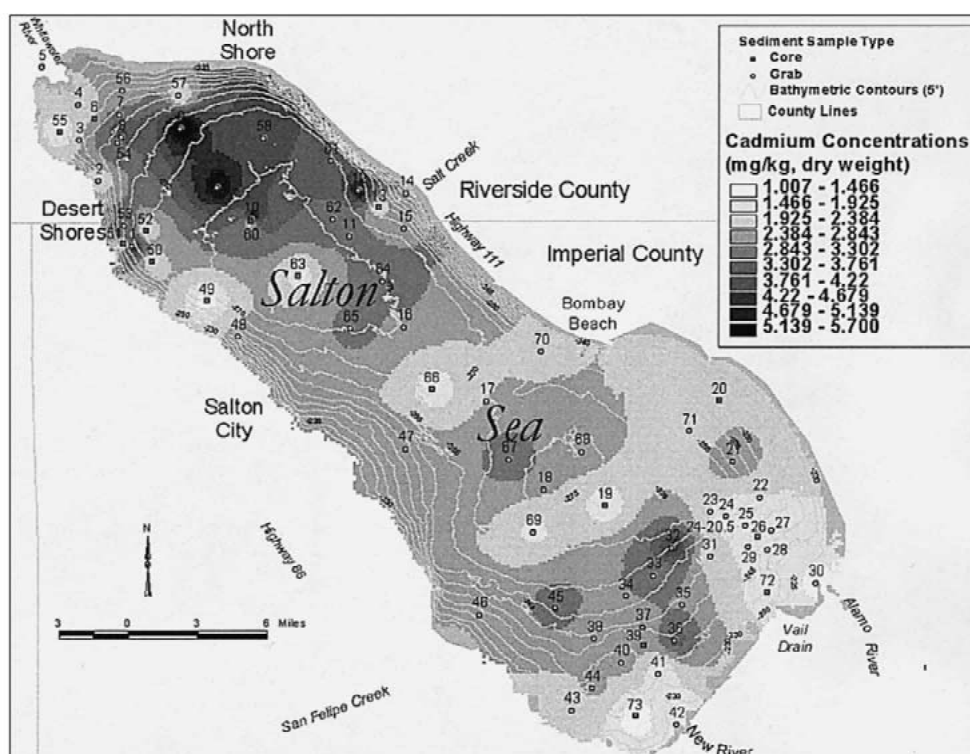


Figure 5. Cadmium concentrations.

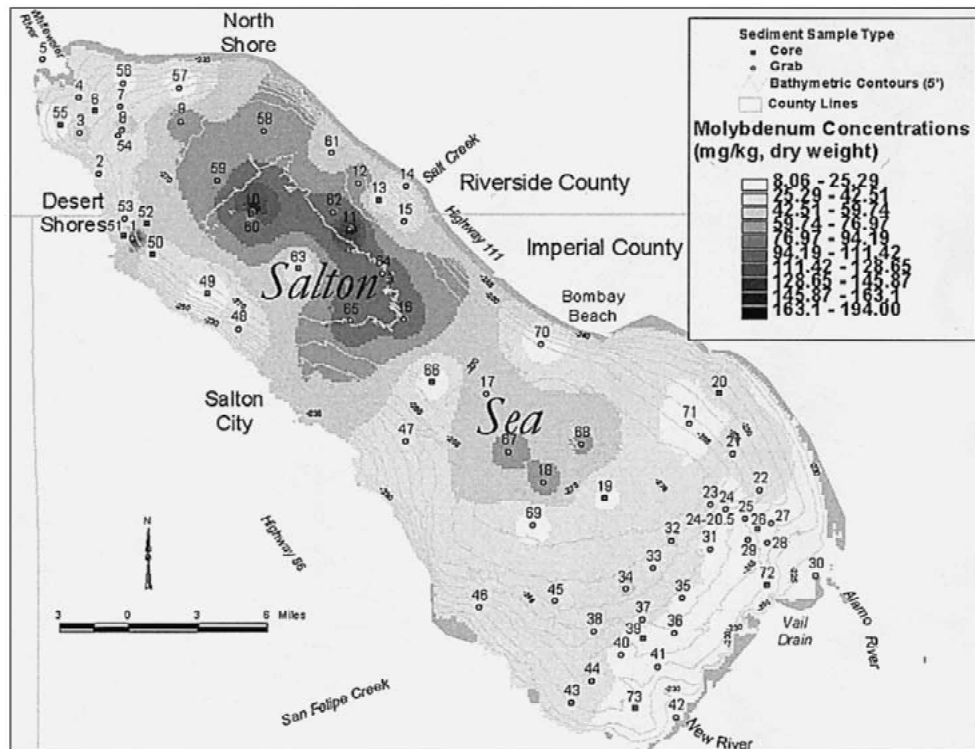


Figure 6. Molybdenum concentrations.

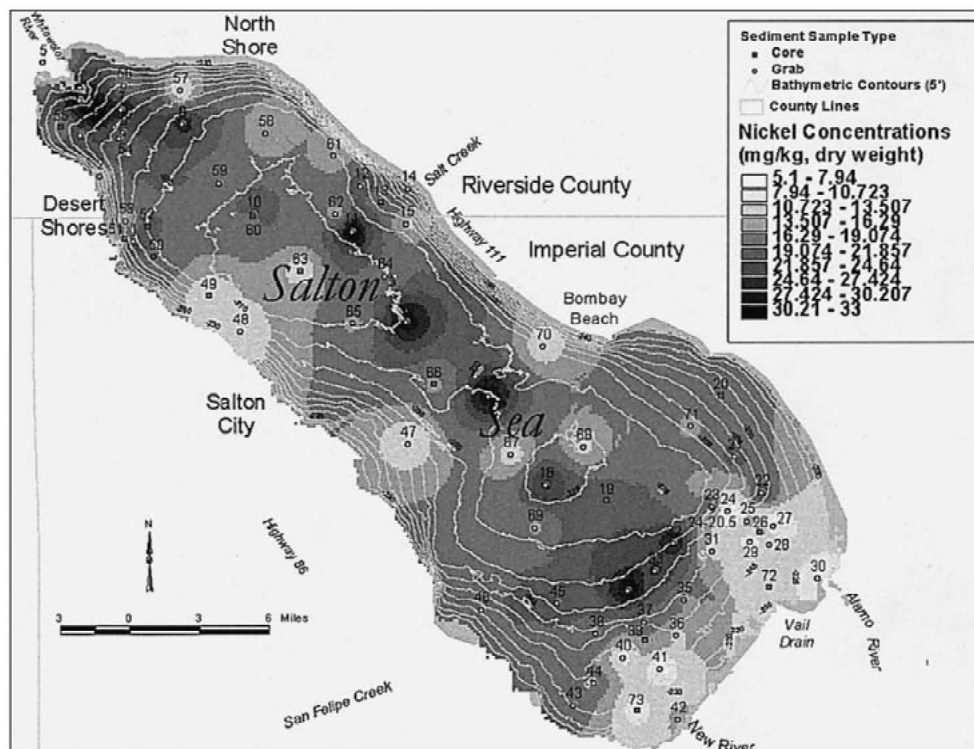


Figure 7. Nickel concentrations.

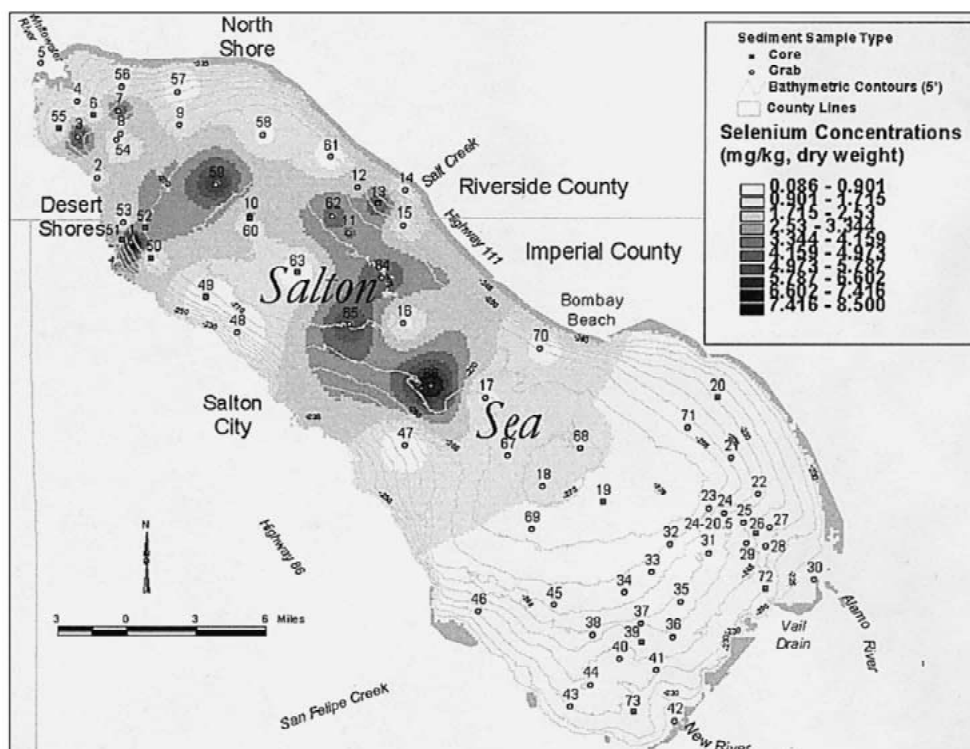


Figure 8. Selenium concentrations.

Carbon disulfide concentrations ranged from 15 to 1800  $\mu\text{g/kg}$ . The highest concentrations of carbon disulfide were near the mouth of the Whitewater River. Concentrations of 2-butanone ranged from 11 to 150  $\mu\text{g/kg}$ . The highest concentration of 2-butanone was detected in the northern portion of the Sea, offshore from Salton Sea State Park.

Only two other sediment samples contained detectable concentrations of other volatile organic compounds, including o-xylenes, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, naphthalene, and n-propylbenzene. These chemicals appeared to be very localized and non-pervasive.

One of the most significant findings of this study was that semi-volatile organic compounds, chlorinated pesticides, PCBs, organophosphate and nitrogen pesticides, and chlorinated herbicides were not detected in the sediment samples analyzed. Low concentrations of organochlorine pesticides may not have been detected in this study because of elevated reporting detection limits; however, a number of previously detected concentrations for these pesticides were above the laboratory detection limits for this study, yet nothing was detected even from our much larger data set.

The detection limit problem resulted from the characteristics of Salton Sea sediments, which contain very high levels of organic carbon and sulfur. For each analysis, the laboratory attempted to achieve the lowest detection limit possible based on the available sample size and the matrix sampled.

## Conclusions

The results of this study indicate that a number of metals and metalloids including cadmium, copper, molybdenum, nickel, zinc, and most notably selenium, are present at elevated concentrations in Salton Sea sediment at concentrations that could be of potential ecological concern. These elements were found in higher concentrations in the northern part of the Sea and appear to be generally limited to the upper 30 cm of sediment. There did not appear to be any strong correlation between the sand, silt, or clay content with the areas of elevated metals and metalloids. Relatively low concentrations of volatile organic compounds including acetone, 2-butanone, and carbon disulfide were widespread in the sediments throughout

the Sea, and have therefore been interpreted to be associated with natural anaerobic biologic decomposition processes within the sediments rather than an anthropogenic source. One of the most significant findings of this study was that semi-volatile organic compounds, chlorinated pesticides, PCBs, organophosphate and nitrogen pesticides, and chlorinated herbicides were not detected at elevated concentrations in the sediment samples analyzed indicating that the Sea was much healthier with respect to contamination than originally suspected.

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